# APPENDIX 6

## EXTRACTION WELL DEVELOPMENT TECHNICAL MEMORANDUM

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# DEVELOPMENT OF EXTRACTION SCENARIOS

## 1.0 INTRODUCTION

This appendix describes nine extraction scenarios that were simulated using the project flow model. The objective of the extraction system is to prevent further migration of the Muscoy Plume. The extraction scenarios were simulated for the purpose of comparing the efficiency and feasibility and eventually to select the optimal remediation extraction system for the Muscoy Plume OU.

## 1.1 BACKGROUND

The extraction scenario simulation, described herein for the Muscoy Plume OU, was performed using the project flow model developed for the Muscoy Plume OU. The project flow model for the Muscoy Plume OU was developed by updating previous modeling effort performed for the Newmark OU RI/FS.

Initially, the groundwater modeling was performed for the Newmark OU. This effort involved: (a) the development of the project flow model for the Newmark OU, and (b) the application of the project flow model for the evaluation of extraction scenarios for the Newmark OU. The following reports resulted from that modeling effort:

- Newmark Project Flow Model Technical Memorandum, Part I (October 1991)
- Newmark Project Flow Model Technical Memorandum, Part II (September 1992)
- Newmark RI/FS Report, Appendix J - Newmark Project Flow Model Technical Memorandum (March 1993)
- Newmark RI/FS Report, Appendix M - Development of Extraction Scenarios (March 1993)

The Newmark project flow model covered a wide area including the Muscoy Plume OU area. The Newmark project flow model was well calibrated to include the Newmark plume area, but it was only partially calibrated in the area where Muscoy Plume was located. Because the Muscoy Plume OU was considered to be "far field" (or located far away) from the Newmark plume area, characteristics (e.g., boundary condition) of the Muscoy Plume area would not have influenced the modeling results of Newmark plume area. For this reason, the partial calibration of the Muscoy Plume area was considered satisfactory for the Newmark project flow model.

The Newmark project flow model was further calibrated to better define the Muscoy Plume OU. This resulted in the project flow model for the Muscoy Plume OU, and the resulting report:

- Muscoy Groundwater Modeling Memorandum (November 1993)

The Muscoy Groundwater Modeling Memorandum essentially presented the results of the Muscoy Plume OU project flow model. It did not present details of the modeling development aspect for the Muscoy Plume OU (e.g., grid system, input data, boundary condition, etc.). Those details are presented in Section 2.0 of this Appendix. The remaining sections of the appendix are divided into four more sections: (1) development of extraction scenarios; (2) average groundwater velocities; (3) limitations of the extraction scenario results; and (4) references.

## 2.0 REVIEW OF PROJECT FLOW MODEL DEVELOPMENT

The groundwater flow model used during the Muscoy Plume OU RI/FS was originally developed for the Newmark OU RI/FS. The model was modified and recalibrated during the scoping phase of the Muscoy OU RI/FS (URS 1993) to evaluate or screen groundwater extraction and injection alternatives within the Muscoy Plume OU investigation area. This section details the development of the Muscoy Plume OU project model based on the Newmark OU project flow model.

### 2.1 NEWMARK OU PROJECT FLOW MODEL

There were two stages in the development and calibration of the Newmark OU project flow model using the MODFLOW program: the steady-state flow model and the transient-state flow model. Transient-state groundwater movement or storage in an aquifer system reflects a change in storage due to the differences in the input and output; in steady-state conditions, however, the change in storage is equal to zero since the input is always equal to the output.

The steady-state flow model was simulated and calibrated for the time period between January 1982 to January 1986. The input data and boundary conditions are described in Sections 1.5 and 2.3 of Appendix J of the Newmark OU RI/FS Report (URS 1993). The transient-state flow model was simulated and calibrated for the time period between January 1986 to December 1990. The input data and boundary conditions resulting from the calibration of the steady-state flow model were used as the initial conditions for the transient-state flow model. Some of the input data and boundary conditions (e.g., transmissivities, recharge values) were refined in order to calibrate the transient-state flow model.

The calibrated transient-state flow model then became the project flow model which was used for simulation of the extraction scenarios for the Newmark OU RI/FS (Appendix M of the Newmark OU RI/FS Report, URS 1993). The measured recharge, streamflow, pumpage from existing municipal water supply wells, and head values for the January 1986 through December 1990 period were used in all extraction scenario simulations.

Several MODFLOW runs were performed during the steady-state and transient-state model calibration, and during the extraction scenario simulations. Model runs 7D to 16B represented steady-state calibration. Model runs 17A to 25D represented transient-state calibration, and model runs 27A to 39B represented the simulation of the extraction scenarios.

### 2.2 MUSCOY PLUME OU PROJECT FLOW MODEL

The Newmark OU project flow model was further modified and calibrated during the scoping phase of the former Muscoy OU work assignment to become the Muscoy Plume OU project flow model. The primary objectives of the scoping phase modeling effort were:

- To identify areas of high uncertainty and critical data gaps in the Muscoy Plume OU.

- To evaluate the feasibility of a preliminary groundwater extraction system; and, if feasible, provide a technical basis for selection of an extraction scenario to contain groundwater contamination in the Muscoy Plume OU.

The results of the project flow model for the Muscoy Plume OU are presented in Muscoy Groundwater Modeling Memorandum, November 1993. The details of the project flow model development are presented in this section.

Development of the project flow model consisted of several processes:

- Development of the conceptual model;
- Definition of the model area;
- Definition of the grid system;
- Preparation of the input data; and
- Calibration of the steady-state and transient-state flow models.

The development of the above process for the Muscoy Plume OU project flow model was identical to that of the Newmark OU project flow model, provided in the Newmark OU RI/FS Report (URS 1993). By appropriately referencing the Newmark OU RI/FS Report, these processes are described below so that this appendix becomes a stand-alone document.

Development of the conceptual model and definition of the model area for the Muscoy Plume OU was the same as for the Newmark OU, and this is described in Subsection 1.4 of Appendix K of the Newmark OU RI/FS Report (URS 1993). The remaining processes for the development of the project flow model are presented below.

The MODFLOW (McDonald and Harbaugh 1988) groundwater flow program was used to simulate the groundwater flow for the model area. MODFLOW is a groundwater flow program capable only of simulating the advection processes that take place in the groundwater system. It cannot simulate contaminant transport. MODFLOW can therefore only be used to simulate the direction and, to a limited extent, the rate of advective transport of dissolved TCE and PCE. PATH3D© (Zheng 1991) and SURFER® (Golden Software, Inc. 1993) were used as post-processors for the MODFLOW output data. PATH3D©, a groundwater path and travel-time program, utilized the input data and unformatted head files of MODFLOW simulations to:

- Create contours of the calculated heads;
- Simulate the pathlines of imaginary particles placed in the Muscoy Plume OU; and
- Delineate capture-zones for each extraction scenario.

SURFER® (Golden Software, Inc. 1993) is a graphics program, which utilizes the head contour files created by PATH3D© to produce plots displaying the head contours, particle pathlines, and the overall response to groundwater extraction.

### 2.2.1 Grid System

For the Newmark OU, a grid system of 3360 square cells (42 columns and 80 rows) with constant grid spacing was constructed for the preliminary steady-state model. Each cell measures 820.25 feet in both the x- and y-directions. The grid system for the study and model area is displayed in Figure 2 of Appendix K of the Newmark OU RI/FS Report (URS 1993). The same grid system was used for the Muscoy OU.

### 2.2.2 Input Data for Project Flow Model

The input data for simulation of the project flow model using the MODFLOW program were arranged into seven categories of input files:

- Hydrogeologic layers.
- Boundary conditions.
- Initial head conditions.
- Surface water and groundwater interaction.
- Hydraulic conductivity and transmissivity values.
- Well pumpage.
- Vertical leakance values.

#### 2.2.2.1 Hydrogeologic Layers

The model area consists of igneous and metamorphic basement rock that was downdropped between the San Andreas and San Jacinto faults. The basin is filled with alluvial deposits which spread around the bedrock hills and reach a thickness of at least 2,100 feet in the southern portion of the model area northeast of the San Jacinto fault (Hardt and Hutchinson 1980). From here, the basin deposits become progressively thinner towards the northwest and north near the San Bernardino Mountains. Figure 15 in Appendix J (of the Newmark OU RI/FS) shows interpreted thickness of the alluvium for the model area. Figure 15 in Appendix J (of the Newmark OU RI/FS) was modified from Hardt and Hutchinson (1980) using additional well information. Figure 16 in Appendix J (of the Newmark OU RI/FS) depicts the interpreted surface of the bedrock for the model area.

Several cross-sections were constructed from a detailed analysis of approximately 100 drillers' logs. Interfingering clay lenses that are evident in the individual drillers' logs were grouped together into one middle clay unit that acts as a confining layer for the lower aquifer. Table 1 in Appendix J (of the Newmark OU RI/FS) shows the top and bottom elevations of the middle confining clay unit chosen from each drillers' log. The detailed cross-sections were then compiled into two conceptual cross-sections. Figure 5 in Appendix J (of the Newmark OU RI/FS) shows the locations of the conceptual cross-sections. Figure 6a in Appendix J (of the Newmark OU RI/FS) represents a north/south cross-section and Figure 6b in Appendix J (of the Newmark OU RI/FS) represents an east/west cross-section.

After further analysis of the cross-sections, the model area was divided into two major aquifers. The area north of Shandin Hills consists of one unconfined aquifer. The area just south of Shandin Hills is comprised of two aquifers: the upper aquifer, an extension of the unconfined aquifer north of Shandin Hills and the lower aquifer, a separate, confined aquifer. However, for modeling purposes the aquifer north of Shandin Hills was separated into two aquifers by extending the middle confining clay unit through this area at a "zero-foot" thickness and making the lower aquifer (layer 2) approximately 25 feet thick.

To further define the aquifer system for model representation, two structure maps were constructed for the middle confining clay unit using the elevations listed in Table 1 of Appendix J (of the Newmark OU RI/FS). Figure 7 in Appendix J (of the Newmark OU RI/FS) shows the elevations for the top surface of the middle confining clay unit, and Figure 17 of Appendix J (of the Newmark OU RI/FS) shows the elevations for the bottom surface of the middle confining clay unit.

The middle confining clay unit is predominantly clay but includes varying amounts of sand and gravel. The unit is at least 300 feet thick in the central part of the study area near the 7th Street well and thins towards the northern parts of the study area. The top surface of the middle confining clay unit ranges from 1,016 feet above sea level at the Darby well just south of the southwest corner of Shandin Hills to approximately 580 feet above sea level in the central part of the model area near Warm Creek.

The middle confining clay unit was not modeled as a separate hydrologic layer but rather its thickness was embedded in the vertical leakance values for the overlying unconfined aquifer (layer 1). The vertical leakance values for the middle confining clay unit will be discussed in more detail later in this section. The upper model layer (layer 1) is above the middle confining clay unit and the lower model layer (layer 2) is below the middle confining clay unit. The greatest thickness of water-bearing deposits is in layer 2. The bottom elevations for layer 1 will correspond to the top elevations of the middle confining clay unit and the top elevations for layer 2 will correspond to the bottom elevations of the middle confining clay unit. Since the designated bottom of layer 1 and top of layer 2 do not coincide in the southern area of the model area, the project flow model recognizes the break between the layers as a middle confining clay unit. The actual thickness of the middle confining clay unit is figured into the vertical leakance values, which will be described later in this section.

#### 2.2.2.2 Boundary Conditions

The boundary conditions for the model area were defined by the geometry of the model area, by the groundwater/surface water flow conditions, and by the geologic structures (faults, subsurface groundwater barriers, and impermeable bedrock features) in the area. Several boundary condition subroutines available in the project flow model were used to represent the actual boundary conditions within the model area. Actual boundary conditions for the model area were represented in the project flow model as no-flow and head-dependent conditions. The boundary conditions are assigned to the individual cells of the model, both for layers 1 and 2.

<u>No-flow Conditions</u>

No-flow conditions were simulated in the model for several impermeable areas that include bedrock hills, mountains, and fault zones. Shandin Hills, Badger Hill, Wiggins Hill, and Perris Hill are bedrock hills that impede groundwater flow within the model area. The San Andreas and San Jacinto faults form no-flow boundaries that border the northeastern and southwestern boundaries of the model area. Figure 18 in Appendix J (of the Newmark OU RI/FS) displays the no-flow cells (impermeable areas). The hydraulic conductivity values for the upper verses lower aquifers of the southern region of the model area will be discussed later in this section.

**<u>Head-dependent Conditions</u>**

Head-dependent conditions were simulated using the General-head Boundary package. Head-dependent conditions were assigned to the eastern and western boundaries of the model area. Head-dependent conditions were also assigned to the most upgradient and downgradient positions of the streams where they enter or leave the model area. Furthermore, head-dependent conditions were assigned to the upper aquifer cells because the streams influence only the upper aquifer.

Head-dependent conditions were assigned to the most upgradient or downgradient positions of the following streams and canyons which are displayed in Figure 18 of Appendix J of the Newmark OU RI/FS:

- The upper cell of Devil Canyon where it intersects the San Andreas fault.
- The upper two cells of Waterman Canyon where it intersects the San Andreas fault.
- The upper eleven cells of Lytle Creek Wash located on the western boundary of the model area.
- The upper cell of East Twin Creek located on the eastern boundary of the model area.
- The upper five cells of the Santa Ana River located on the eastern boundary of the model area.
- The upper cell of San Timoteo Wash located on the eastern boundary of the model area.
- The lower six cells of the Santa Ana River where it crosses the San Jacinto fault.

Head-dependent conditions allow for flow to enter or leave a cell i,j,k from an external source. The location of each cell i,j,k is designated by the row (i), column (j), and layer (k). This flow, $Q_{bi,j,k}$, is proportional to the difference between the head in the cell, $h_{i,j,k}$, and the head assigned to the external source, $h_{bi,j,k}$. Thus, a linear relationship between flow into the cell and head in the cell is established,

$$Q_{bi,j,k} = C_{bi,j,k} (h_{i,j,k} - h_{bi,j,k}) \qquad (1)$$

where, $C_{i,j,k}$ is the conductance between the external source and cell i,j,k (McDonald and Harbaugh 1988). Conductance equals the horizontal hydraulic conductivity times the cross-sectional area of the external source.

Several input parameters were needed to simulate the flow across the head-dependent cells:

- Heads for the external source.
- Cross-sectional area for the external source.
- Horizontal hydraulic conductivity of the external source area.

Flow values across each head-dependent cell for the upper and lower cells of these streams were calibrated with the streamflow data for the corresponding gaging station locations. (Table 2 in Appendix

J of the Newmark OU RI/FS lists the streamflow data that were used in the steady-state calibration.) Table 9 in Appendix J lists the streamflow data that were used in the transient-state calibration. Figure 10 in Appendix J of the Newmark OU RI/FS illustrates the locations of the gaging stations.

#### 2.2.2.3 Initial Head Conditions

The project flow model for the Newmark OU was calibrated for two phases: steady-state and transient-state. Steady-state verses transient-state is described in more detail in Section 2.1 of Appendix J of the Newmark OU RI/FS Report. The steady-state model was calibrated from 1982 to 1986. This period was chosen to run the steady-state phase of the model because groundwater elevations remained fairly constant during this time. Also, the total inflow and outflow of water from the study area did not vary significantly during this time period (Hardt and Freckleton 1987).

January 1982 water elevations were used for the initial head conditions. These water elevations were obtained from Hardt and Freckleton (1987). Figure 11 of Appendix J (of the Newmark OU RI/FS Report) displays the January 1982 initial water elevations for the upper aquifer. Figure 12 of Appendix J (of the Newmark OU RI/FS Report) displays the January 1982 initial water elevations for the lower aquifer.

The transient-state model was calibrated from January 1986 through December 1990. The January 1986 water elevations calibrated for the steady-state model were used for the initial head conditions of the transient-state model. Figure 19 in Appendix J (of the Newmark OU RI/FS Report) displays the January 1986 initial water elevations for the upper aquifer. Figure 20 of Appendix J (of the Newmark OU RI/FS Report) displays the January 1986 initial water elevations for the lower aquifer.

#### 2.2.2.4 Surface Water and Groundwater Interaction

Surface water enters the model area through various streams flowing from the north out of the San Bernardino Mountains and from the east and west sides of the model area. Most of the surface water enters the model area through Devil Canyon and Waterman Canyon-East Twin Creek. These canyons collect runoff water from the San Bernardino Mountains. The remainder of the surface water enters the east side of the model area through Warm Creek, Santa Ana River and San Timoteo Wash, and the west side of the model area through Lytle Creek Wash. Some surface water leaves the model area intermittently through the Santa Ana River where it crosses the San Jacinto fault to the south (Hardt and Hutchinson 1980).

Groundwater movement in the model area follows the surface-drainage pattern. Groundwater generally moves southward in the model area, except in the Lytle Creek area where it moves southeastward and converges toward a common line of discharge at the San Jacinto fault beneath the Santa Ana River. The potentiometric head is above the confining beds in this area, and because the San Jacinto fault restricts groundwater flow, groundwater is forced through and around the clay beds into the overlying strata and onto the land surface. Consequently, significant components of vertical flow are created in the groundwater flow regimen. Historically, potentiometric heads above land surface existed in the Warm Creek area adjacent to the north side of the San Jacinto fault (Hardt and Hutchinson 1980).

Surface water is piped into the model area and released at three recharge facilities (percolation basins) at the base of the San Bernardino Mountains predominantly during the dry, summer months (Figure 10 in Appendix J of the Newmark OU RI/FS Report). Sweetwater spillway lies just south of Devil Canyon. The Badger recharge area is located to the west of Badger Hill. The Waterman Canyon-East Twin Creek facility contains percolation basins just south of Waterman Canyon.

Surface-water inflow and outflow for the model area has been measured at selected gaging stations (Figure 10 in Appendix J of the Newmark OU RI/FS Report). The data show, except during high flows caused by infrequent flooding, the inflows are much larger than the outflows. Thus, it is concluded that most of the surface flow that enters the valley percolates into the aquifer (Hardt and Hutchinson 1980).

Generally, the flow from small streams (Devil Canyon, Waterman Canyon-East Twin Creek, San Timoteo Wash, and Warm Creek) is recharged locally into the aquifer within a few miles of the mountain front. Therefore, the recharge areas for Devil Canyon and Waterman Canyon-East Twin Creek only occur at the percolation basins. South of these basins, the streams function as subsurface discharge areas for groundwater in the model area. In the subsurface discharge areas of the streams, groundwater flows towards the permeable, subsurface streambeds. The groundwater is discharged atmospherically by evapotranspiration where groundwater is within 10 feet of the ground surface. The recharge areas for Warm Creek and San Timoteo Wash are located outside the Newmark model area to the northeast. Consequently, the portions of the Warm Creek and San Timoteo Wash located within the model area function as discharge areas for groundwater flow.

Large flow rates are transmitted by the larger streams (Santa Ana River and Lytle Creek) in a short time during flood periods. Surface water and groundwater discharge of these flood flows out of the model area occurs primarily where the Santa Ana River crosses the San Jacinto fault. The General-head Boundary package of the project flow model was used to simulate the groundwater flow into and out of the model area across the upgradient cells of the streams. The River package of the project flow model was used to simulate the effects of flow between the surface-water features and the groundwater system. The river package was set up so that surface water recharged the groundwater at all isolated percolation basins and percolation basins connected with the upgradient positions of the streams (Devil Canyon and Waterman Canyon-East Twin Creek). The remainder of the streams were set up as groundwater discharge areas. Figure 18 in Appendix J (of the Newmark OU RI/FS Report) illustrates the model area portions effected by the streams, percolation basins, and ponds.

Flow between the stream and the groundwater system is characterized by

$$QRIV = CRIV\ (HRIV - h_{i,j,k}) \qquad (2)$$

where, QRIV is the flow between the stream and the aquifer and taken as positive if it is directed into the aquifer; HRIV is the head in the stream; CRIV is the hydraulic conductance of the stream-aquifer interconnection; and $h_{i,j,k}$ is the head at the node in the cell underlying the stream reach. The term for the idealized streambed conductance (CRIV) as it crosses an individual cell is further defined by

$$CRIV = (K \times L \times W)/M \qquad (3)$$

where, L is the length of the stream as it crosses the node; W is the stream width; M is the thickness of the streambed layer; and K is the hydraulic conductivity of the streambed material (McDonald and Harbaugh 1988).

### 2.2.2.5 Hydraulic Conductivity Values

Hydraulic conductivity is the quantity of water that will flow through a unit cross-sectional area of a permeable material per unit of time under a unit of hydraulic gradient at a specified temperature. In the project flow model, hydraulic conductivity values were assigned for both the upper and lower aquifers. Aquifer tests (specific-capacity and pump tests) were used to quantify the hydraulic conductivity values for the model area. Table 10 in Appendix J (of the Newmark OU RI/FS) lists the hydraulic conductivity values used in the project flow model. Figure 21 in Appendix J (of the Newmark OU RI/FS) displays the calibrated hydraulic conductivity values used in the project flow model for layers 1 and 2.

Faults and impermeable bedrock hills were represented as either no-flow areas or with low hydraulic conductivity values. A hydraulic conductivity of $2.83 \times 10^{-8}$ ft/day (for upper model layer) and a transmissivity of $2.83 \times 10^{-12}$ $ft^2$/day (for lower model layer) were used for the San Andreas and San Jacinto faults and the bedrock hills. The hydraulic conductivity values of the alluvium were used in the areas where streams cross the San Andreas and San Jacinto faults for the upper modeling layer.

### 2.2.2.6 Well Pumpage

Well pumpage ($ft^3$/day) was also simulated in the flow model. Most of the discharge from the groundwater system in the model area is from water-supply wells. Well pumpage information for steady-state model (time period between January 1982 through January 1986) was obtained from the Western Watermaster via Wesley Danskin of the U.S. Geological Survey. Well pumpage information for the transient-state model (time period between January 1986 through December 1990) was obtained from various water agencies:

- City of San Bernardino Water Department
- City of Riverside Public Utilities Department
- West San Bernardino City Water District
- City of Colton Public Works Department
- Meeks & Daley Water Company (now Elsinore Valley Municipal Water Department)
- Riverside Highland Water Company
- East Valley Water District
- City of Rialto Water Division
- Muscoy Mutual Water Company No. 1

The well pumpage data were arranged in average quarterly values for each year. Well pumpage for each water-supply well active between January 1986 through December 1990 of the transient-state model were used in the calibration of the transient-state model and then used in the predictive simulations for the extraction scenarios. Well pumpage of each water-supply well for the last quarter of 1990 (October, November, and December) are listed in Table 12 in Appendix J of the Newmark OU RI/FS Report. The location of these wells is shown in Figure 22 in Appendix J of the Newmark OU RI/FS Report.

Since the model area is represented by two layers, pumpage for each layer was estimated by well depth, location, and length of screens. Pumpage was assigned to the upper model layer for wells screened only in the upper aquifer. Pumpage for wells screened only in the lower aquifer was assigned to the lower model layer. Pumpage from wells screened in both aquifers was prorated, depending on the length of screens in each aquifer system. The pro-rated discharge from these wells was allocated to the nearest nodes. As many as seven wells were grouped together to represent the composite pumpage for one model cell.

#### 2.2.2.7 Vertical Leakance Values

In order to represent the hydrologic connection between the two layers of the model, vertical leakance values were estimated for the middle confining clay unit that separates the upper and lower aquifer in the souther region of the model area. Leakance is the ratio of the vertical hydraulic conductivity of the clay material to the thickness of the middle confining clay unit. In other words, leakance is used to quantify the rate at which water moves vertically through a particular clay unit into the aquifer. Within the model area, some exchange of groundwater between the upper and lower aquifers occurs through the middle confining clay unit.

Initially when leakance values were assigned for the steady-state model, a vertical hydraulic conductivity of $10^{-8}$ cm/sec ($2.83 \times 10^{-5}$ ft/day) was assumed for the middle confining clay unit (Freeze and Cherry 1979). The thicknesses of the middle confining clay unit ranged from 30 to nearly 300 feet south of Shandin Hills. The resultant leakance values for the middle confining clay unit of the steady-state model ranged from $9.43 \times 10^{-7}$ to $1.00 \times 10^{-7}$ (ft/day)/ft (Table 1 in Appendix J of the Newmark OU RI/FS Report).

During the calibration of the transient-state model, leakance values for the confining clay unit in the southern region of the study area were increased by factors of 10 to $10^4$. The leakance values for the northern edge of the confining clay unit were increased by approximately a factor of $10^4$; the leakance values for the middle area of the confining clay unit next to the San Jacinto fault were reduced by a approximately a factor of 10. Figure 12 in Appendix J (of the Newmark OU RI/FS Report) shows the area of the model area that contains the confining clay unit. Table 11 in Appendix J (of the Newmark OU RI/FS Report) gives the representative leakance values for selective water-supply well areas that were used in the transient-state model. Table 11 in Appendix J (of the Newmark OU RI/FS Report) also shows the leakance value of 0.1 $day^{-1}$ that was used for the northern region of the model area where no substantial confining clay unit exists. This is shown for areas around the Newmark wells, Waterman Avenue well, 30th and Mountain View well, 31st and Mountain View well, and Lynwood well.

### 2.2.3 <u>Calibration of the Steady-State and Transient-State Flow Models</u>

As previously stated, the project flow model for the Newmark OU was further modified and recalibrated during the scoping phase of the former Muscoy OU work assignment. This resulted in the project flow model for the Muscoy Plume OU. The parameters used in MODFLOW model run 37A for the Newmark OU constituted the project flow model for the Newmark OU. The details of this run was given in the Newmark OU RI/FS Report (URS 1993). The Run 37A for the Newmark OU was renamed as Run 42A, and it was used to initiate the transient-state model calibration for the Muscoy Plume OU. The Run 42A provided satisfactory results for the steady-state conditions at the Muscoy Plume OU. Therefore, no calibration for steady-state condition was performed, and all the calibration runs were aimed at transient-state. A brief summary of the calibration runs are presented below.

A total of 24 modeling runs were performed in the following order to:

- Identify areas of high uncertainty and critical data gaps in the Muscoy Plume OU;

- Evaluate the feasibility of a preliminary groundwater extraction system; and
- establish a project flow model.

A preliminary series of model runs (18) was conducted to identify data gaps and to evaluate what impacts that these data gaps may have on the model. These attempts to further calibrate the model, concentrating on the Muscoy Plume OU, were conducted through an iterative process. Calibration was sufficiently successful for use during the FS and several recommendations for further model improvement were proposed. The proposed recommendations may be implemented during the Source OU RI/FS.

Model runs 51B, 51C, and 51D (last 3 runs of the 18 runs) were conducted to simulate known pumping rates from the Baseline Feeder wellfield. This wellfield consists of municipal supply wells near 9th Street and Mt. Vernon Avenue and 9th and Perris Streets. The pumping rates were obtained from the San Bernardino Valley Municipal Water District report, "Baseline Feeder Wells, Ninth and Perris Street, Results of Drilling, Testing, and Recommended Pump Design," dated May 1990. If the testing results are assumed to represent accurate, long-term head drawdowns, then model capture predictions should be conservative because the simulated drawdowns are less than the drawdowns calculated in the test analysis. Uncertainty still exists, however, because the test analysis was based on a relatively short pumping period (24 hours) and drawdowns observed after this pumping period were linearly projected up to one year. If the linear basis for the pumping test projections is not valid, then the project flow model simulations may be less conservative.

After completing the 18 runs, the next 5 runs (Runs 52A, 52B, 52C, 53A, and 54A) were performed to evaluate the feasibility of a preliminary groundwater extraction system. These runs established the preliminary location of extraction and injection wells and pumping and injection rates.

The last run of the total of 24 model calibration runs, Run 55A, was performed to further calibrate the model. Preliminary model calibration after Run 55A was considered complete and Run 55A constituted the project flow model for the Muscoy Plume OU. The project flow model was considered sufficiently calibrated to predict pumping scenarios during the FS; however, a greater level of certainty in the model is needed before it should be applied to RD. The project flow model will be updated as data from the Source OU RI/FS are collected. Model run 55A was considered the best calibration run and was used as a base for subsequent simulations during Muscoy Plume OU predictive modeling efforts.

## 3.0 DEVELOPMENT OF EXTRACTION SCENARIOS

This section describes the nine extraction scenarios that were simulated using the project flow model (defined in Subsection 2.2). The extraction scenarios were simulated for the purpose of comparing the efficiency and feasibility of remediation extraction systems for the Muscoy Plume OU.

This section is divided into two subsections: (1) the rationale for the selection of extraction regions and extraction scenarios, and (2) the details and results of each extraction scenario.

### 3.1 EXTRACTION REGIONS AND EXTRACTION SCENARIOS

A total of nine extraction scenarios were simulated during predictive modeling. Each extraction scenario consisted of pumping from one or a combination of three extraction regions. For modeling purposes, the extraction regions were subdivided into extraction areas that represented either individual extraction wells or groups of extractions wells. It should be noted that the extraction areas were developed for modeling purposes only. The exact locations and number of extraction wells will be determined during remedial design. The locations of the extraction areas are shown in Figure A6-1. The extraction regions for the Muscoy Plume OU consisted of the following:

- Municipal supply wells No. 1 and No. 2 near 19th and Flores Streets (19th Street wellfield);
- Baseline Feeder wells near 9th Street and Mt. Vernon Avenue, and 9th and Perris Streets (Baseline Feeder wellfield); and
- An area perpendicular to the long axis of the contaminant plume, midway between the 19th Street wellfield and the Baseline Feeder wellfield.

The 19th Street wellfield was chosen as an extraction region to evaluate the effectiveness of an existing groundwater treatment plant as part of a remediation strategy. The Baseline Feeder wellfield was chosen to represent an extraction region to evaluate how pumping from this region wells might affect extraction from the leading edge of the contaminant plume. The downgradient edge of the groundwater contaminant plume was chosen as an extraction region for the main purpose of preventing further downgradient contaminant migration.

Two regions were also chosen to represent injection of treated groundwater. The injection regions were used in extraction scenario no. 9 to evaluate aquifer injection as an end-use remedial alternative. One injection region consisted of four areas along the western edge of the contaminant plume; this region was chosen to evaluate injecting the treated groundwater west of the contaminant plume. The second injection region consisted of four areas along the eastern edge of the contaminant plume; this region was chosen to evaluate injecting treated groundwater east of the contaminant plume.

It should be noted that the main purpose for considering groundwater injection was to evaluate an end-use alternative. Injection scenarios were not optimized during the current modeling effort. If the injection end-use alternative becomes part of the selected remedy, additional evaluation to optimize injection well locations and injection rates must be performed.

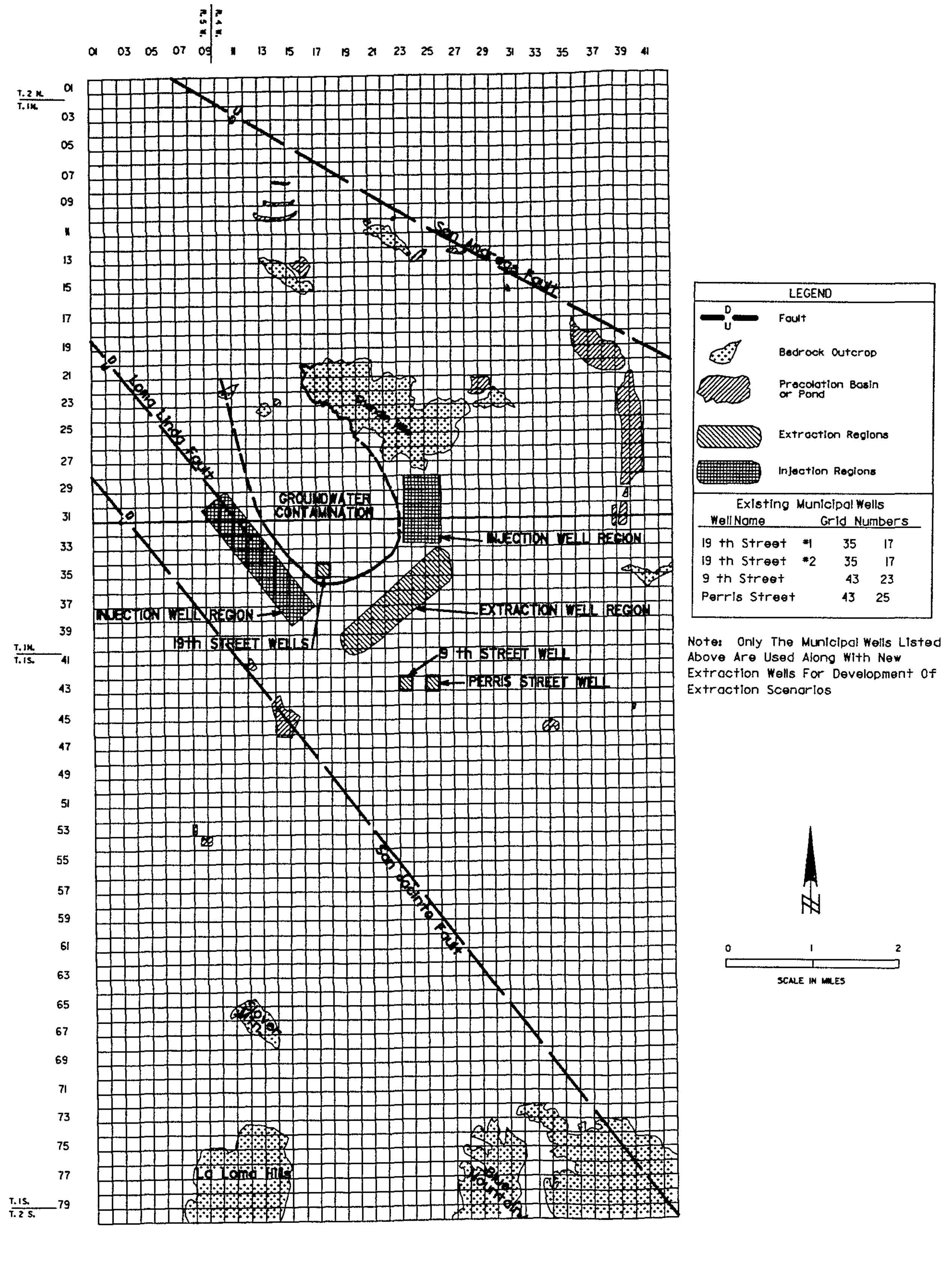


FIGURE A6-1

LOCATION OF EXTRACTION AND INJECTION AREAS

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A total of 23 runs were completed during the development phase of the extraction scenarios. Table A6-1 summarizes the details of the runs. The runs are used in the selection of the nine extraction scenarios discussed in this section. Typically, the development of a single extraction scenario involves many runs. These runs represent an iterative process, in which each run during the iteration is refined to optimize the location, number of wells, and pumping rates. During the iteration cycle, if a run produces satisfactory plume capture, then this run is considered the last run of the iteration cycle, and it also represents the particular extraction scenario.

The nine extraction scenarios were:

- Extraction scenario no. 1 - simulated for a duration of 35 years using the 19th Street and Baseline Feeder wellfields;
- Extraction scenario no. 2 - simulated for a duration of 35 years using the 19th Street wellfield;
- Extraction scenario no. 3 - simulated for a duration of 35 years using three extraction areas located in the downgradient edge of the plume and the 19th Street wellfield;
- Extraction scenario no. 4 - simulated for a duration of 35 years using three extraction areas located in the downgradient edge of the plume and the 19th Street wellfield;
- Extraction scenario no. 5 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume and 19th Street wellfield;
- Extraction scenario no. 6 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume;
- Extraction scenario no. 7 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume (constant pumping rates) and Baseline Feeder wellfield;
- Extraction scenario no. 8 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume (seasonally varied pumping rates) and Baseline Feeder wellfield; and
- Extraction scenario no. 9 - simulated for a duration of 35 years using four extraction areas located at the downgradient edge of the plume, and eight injection areas along the east and west edges of the plume.

As previously noted, the locations of the extraction areas are shown in Figure A6-1. Table A6-2 lists extraction scenario parameters. Extraction scenario no. 1 was simulated to evaluate the effectiveness of plume capture due to combined extraction from existing 19th Street and Baseline Feeder wellfields. This extraction scenario was also known as the No Action scenario. Extraction scenario no. 1 was used to:

- Estimate the position of the Muscoy OU plume 35 years from January 1986; and